Hybrid Poplar Feedstock Production:
Economic Opportunity for Renewable Energy in North America

Brian J. Stanton
GreenWood Resources
Managing Director, Tree Improvement Group

Poplars and their hybrids are the fastest growing trees in the temperate zone with mean annual increments of above-ground biomass approaching 14 dry metric tons per hectare per year culminating in less than ten years as measured in today's commercial plantations. It is not surprising then, that The Department of Energy has identified hybrid poplar as one of the United States' most important feedstocks in their report, "Breaking the Biological Barriers to Cellulosic Ethanol". Although, poplar plantations were first commercialized by the pulp and paper industry as the most opportune strategy to forestall regional shortages in hardwood fiber necessary for the manufacture of premium communication paper grades, the future profitability of the hybrid poplar plantation industry is now widely viewed as contingent upon the development of additional markets including veneers and sawn wood products, engineered wood materials, and energy outlets featuring bio-fuels.

Presently, the cost of growing poplar for pulping fibers varies between $24 and $30 per dry metric ton dependent upon the region of the United States. (Costs reported as a net present value based upon a 6.5% discount rate). Similarly, harvesting costs range from $29 to $40 per metric ton dependent upon processing method. Reductions in both are imperative if the poplar industry is to compete as a dedicated, large-scale, and reliable source of energy feedstock. Such reductions will most likely be achieved through: 1) Development of elite varieties through recurrent breeding of parental species followed by F_1 hybridization and clonal selection to increase yields by 20 to 30 % over current levels, 2) Manipulation of lignin and cellulose biosynthetic pathways using molecular tools now well advanced by the recent sequencing of the *Populus* genome, 3) Refinement of more efficient harvesting and processing technologies as are now being proven out in the European Union, and 4) Exploitation of markets for tradable pollution credits that capitalize on the environmental attributes of poplar cultivation. Finally, conversion to ethanol via indirect fermentation may also offer improvements in the financial analyses of poplar plantations if the businesses of feedstock production and ethanol production can be managed as integrated, rather than separate entities.

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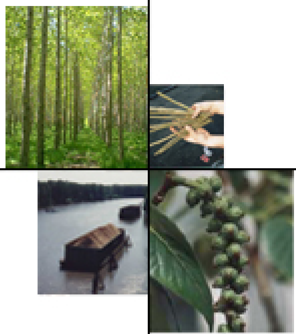


Hybrid Poplar

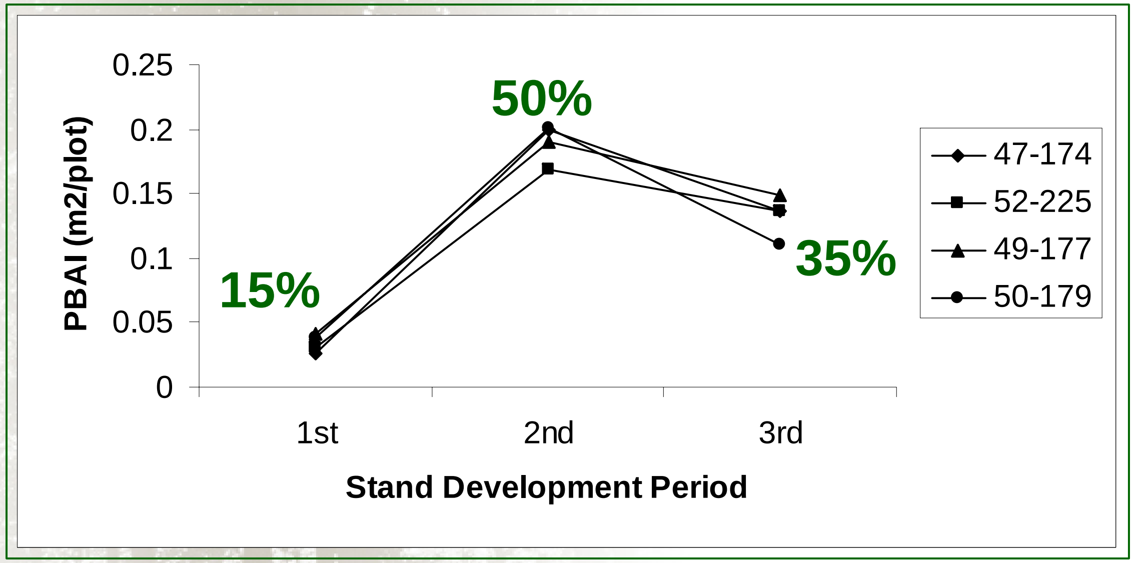
- Genus *Populus*
  - 29 species: Asia, Europe, North America
  - 3 main sections: aspens, cottonwoods, poplars
  - Species hybridization leads to hybrid vigor (e.g. *P. x canadensis, P. x generosa*)
- Agricultural versus forest crop
  - Agronomic practices and equipment
- Fastest growing tree in the temperate zone
  - Acceleration phase of stand development can occur within three years of establishment

Agricultural Style Cropping

Intensive cultivation during establishment phase

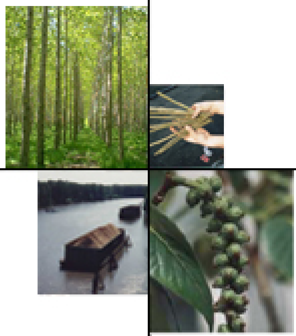
Varietal stands of uniform stem size and wood properties

Fast-Growing Species



Moderately-dense stands harvested after six years

Periodic growth culminates within the 2nd two-year period



U. S. Poplar Plantation Industry: Pulp and Paper Production

Region	Biomass Growth Rate (MT ha^{-1} yr^{-1})	Rotation (yrs)	Area [1] (ha)
Pacific Northwest	13.5	6 to 8	14,000
North Central	9.4	12	10,000
Mississippi River Valley	10.1	8 to 10	11,000

1/ FAO. 2004. Synthesis of Country Progress Reports, 22nd Session, International Poplar Commission, Santiago, Chile, November 28 – December 9, 2004. Working Paper IPC/3, Forest Resources Division, FAO (Rome).

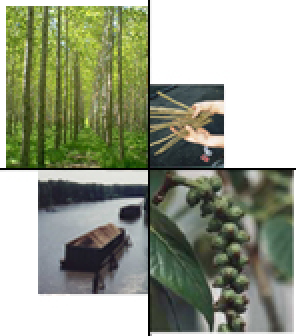
Hybrid Poplar Plantation Industry: An Abridged History

- **1920 – 1930's:** Experimental hybridization begins in U. S. and Canada.
- **1950's:** Institute of Paper Chemistry initiates aspen hybridization.
- **1960 – 1970's**: Crown Zellerbach, Packaging Corporation, Westvaco plantations first appear in the Mississippi River Valley.
- **1980 – 1990's**: James River, Boise Cascade, Potlatch, McMillan Bloedel all establish plantations in the Pacific Northwest.
- **2000's:** Verso Paper, Alberta Pacific begin plantation development in the North Central States and the Canadian prairie.

Poplar Biomass for Renewable Energy: Direct Combustion

Pacific Northwest *P. x generosa*

- Historic use of harvest residue in co-firing boilers
- Age six yield of 81 dry tons per hectare represents 1,600 GJ/ha (based on a gross calorific value of 20 GigaJoules per dry metric ton)
- Poplar wood moisture content varies 50 to 58%



Poplar Biomass for Renewable Energy: Biochemical Conversion

Crop[1]	Glucose (%)	Xylose (%)	Lignin (%)
Corn Stover	34.0	19.5	19.7
Wheat Straw	32.6	19.2	16.8
Switch grass	34.3	22.4	17.4
Hybrid poplar	42.1	16.2	23.5

1/ DOE Biomass Composition data base: http://www.eere.energy.gov/biomass/progs/search1.cgi

Economic Advantages of Poplar Plantations[1]

1. High volume fiber production on a relatively small base of timberlands

2. Early amortization of the costs site preparation, planting, fertilization and cultivation

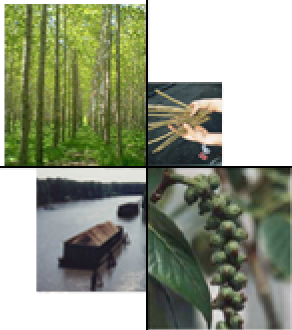
3. Reduced labor costs associated with mechanized operations

4. Lowered 2^{nd} rotation establishment costs associated with coppice regeneration

5. Increased pulping and papermaking efficiencies

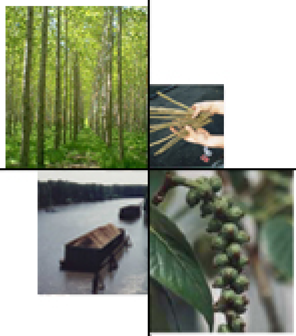
1/ Ribe, J. H. 1974. Will short-rotation forestry supply future pulpwood needs? Pulp and Paper. 48: 72-75.

Biomass Production Costs[1]



Region	Farm Cost ($/MT)	Harvest Cost ($/MT)	Total Cost ($/MT)
Pacific Northwest	27	40	67
North Central	30	31	61
Mississippi Valley	24	29	53

1/ Growing costs reported as NPV (6.5% discount rate) per dry metric ton, inclusive of the cost of land rent, site preparation, planting stock, planting, and crop care through rotation.

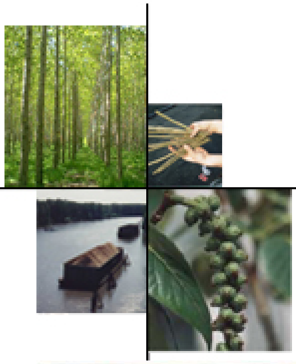


Hybrid Poplar Feedstock Production: Opportunities for Improved Economics

1. Genetic Improvement
   - Biomass yield
   - Feedstock quality

2. Farming Strategy
   - High-density plantings & coppice regeneration
   - Harvesters that combine felling and processing functions

3. Environmental Benefits
   - Monetization of carbon values



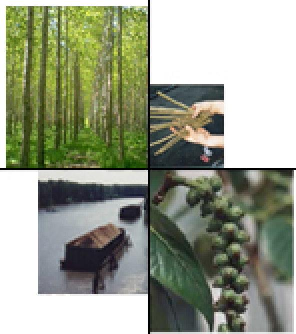
Improving Production Economics: Biomass Yield

Classical approach of hybridization and selection for:

1. Growth rate,
2. Wood density,
3. Wind firmness,
4. Pest resistance,
5. Adaptability to sites of marginal agronomic quality

Target growth rates of 18 to 20 MT ha^{-1} yr^{-1}

Improving Production Economics: Feedstock Quality



Tuskan, G. A. et al. 2006. The genome of black cottonwood *Populus trichocarpa* (Torr. & Gray). **Science** 313: 1596-1604.

1. "Lignin and polysaccharide biosynthesis in wood formation of *Populus trichocarpa*"

   North Carolina State University

2. "Manipulation of lignin biosynthesis to maximize ethanol production from *Populus* feedstock"

   Purdue University

3. "Cellulose and lignin biosynthetic pathways of *Populus trichocarpa*"

   University of California, GreenWood Resources, Michigan Tech University, National Renewable Energy Lab

Improving Production Economics: Farming Strategy

High-density plantings of 5,500 stems per hectare managed on two-year coppice rotations

Combine-like harvesters operating to fell, shred, and load feedstock

Components of Ethanol Production Costs[1]

1. Plantation Establishment & Maintenance	17%
2. Harvesting, Transport & Storage	23%
3. Conversion to Ethanol	60%

1/ Strauss, C. H. and Grado, S. C. 1997. Economics of producing *Populus* biomass for energy and fiber systems. *In*:

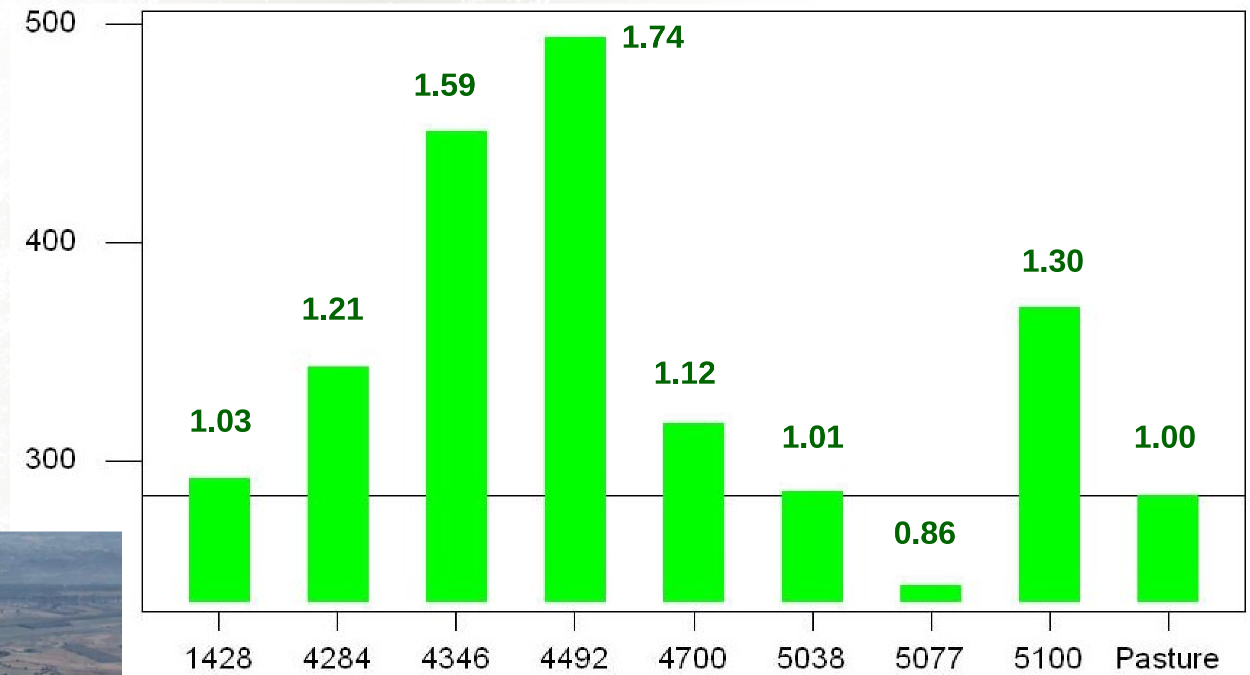
Gen. Tech. Rep. RM-GTR-297. U. S. D. A. Forest Service. pp. 241-248.

Improving Production Economics: Soil Carbon Sequestration

Carbon:

MT ha^{-1}

to 1 m depth



P. x generosa **varieties managed along the lower Columbia River floodplain**

Hybrid Poplar’s Strategic Position

1. **Well developed production system**
   - **Proven varieties and farming techniques**
   - **Established wood handling and storage capabilities**

2. **Excellent opportunity to lower farming costs**
   - **Classical and molecular breeding tools**
   - **Tailored harvesting technology**

3. **Heightened environmental benefits**
   - **Relatively low energy inputs during farming of a perennial crop**
   - **Elevated rates of soil carbon storage, stabilization, nutrient cycling**

Hybrid Poplar for Renewable Energy

"The best alternatives for dealing with increasing demand are to intensify forest management and increase productivity per unit land."

1/ Ranney, J. W., Perlack, R. D., Trimble, J. L., and Wright, L. L. 1985. Specialized hardwood crops for energy and fiber: status, impact, and need. TAPPI Journal. 68: 36-41.